STUDIES ON AL 4.5 WT.%CU ALLOY PROCESSED THROUGH DIE CASTING PROCESS

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Abstract: Al-4.5 wt. % Cu alloy was melted in an electrical resistance furnace. After melting, the melt was transferred into a metaalic die to prepare the casting. The density of the sample was measured using water displacement method. The microstructuaral analysis was carried out using optical metallurgical microscope. For microstructural analysis samples were polished with four grades of emery papers followed by alumina and diamond disc polishing. Finally sampled were etched with Keller's etchant. The microhardness of the samples were measured using Vickers microhardness tester with the dwell time of 10 s. The tensile test was carriedout using universal testing machine to calculate 0.2 % yield strength and ultimate tensile strength of the sample.

Keywords: Aluminum, Copper, Die casting, Microstructure, Mechanical properties

1.INTRODUCTION

1.1 SPRAY ATOMIZATION.

Spray atomisation is the transformation of a liquid into a spray of fine particles in a vacuum or a surrounding gas. The breakdown of the liquid into small particles is achieved when compressed air mixes with the liquid. A spray nozzle is used to generate the atomized spray, which passes through an orifice at high pressure and in a controlled manner.This process is widely utilized when distributing material over across section area and generating a thin surface area over an object homogenously.

1.2 DIE CASTING.

The die casting process is a name given to metal casting processes that requires metal molds or dies. There are really several many processes included under this general name. The die casting process actually can be classified into three main sub-processes. They are:

(i) Permanent casting, also called gravity die casting

(ii) low-pressure die casting.

(iii)high-pressure die casting.

Die casting is the one of the most economical and quickest forming processes.The advantages of this production process are that hundreds of thousands of castings can be produced relatively quickly by using just one mold. All components produced have a uniform quality and involve relatively low unit costs.

1.3 ALUMINUM COPPER ALLOY.

Copper is the most commonly used alloying element almost since the beginning of the aluminum industry, and a variety of alloys in which copper is the major addition were developed. Most of these alloys fall within one of the following groups :

Casted alloys with 5% Cu, often with small amounts of silicon and magnesium. Casted alloys with 7-8% Cu, can often contain large amounts of iron and silicon and appreciable amounts of manganese, chromium, zinc, tin, etc. Cast alloys with 10-14% Cu. These alloys can contain small amounts of magnesium (0.10-0.30% Mg), iron up to 1.5%, up to 5% Si and small amounts of nickel, manganese, chromium.

Wrought alloys with 5-6% Cu can often be found in small quantities of manganese, silicon, cadmium, bismuth, tin, lithium, vanadium and zirconium. Alloys in this type containing of lead, bismuth, and cadmium have superior machinability. Durals, whose basic composition is 4-4.5% Cu, 0.5-1.5% Mg, 0.5-1.0% Mn, sometimes with addition of silicon.

In copper alloys which contains nickel, which can be further subdivided in following groups: the Y alloy type, whose basic composition is 4% Cu, 2% Ni, 1.5% Mg; and the Hyduminiums, which generally have low copper content and in which iron replaces 30 me of the nickel. In most of the alloys present in this group aluminum is the primary constituent and in the cast alloys the basic structure generally consists of cored dendrites of aluminum solid mixed solution, with a huge different types of constituents near the grain boundaries or interdendritic spaces, forming it brittle, more or less continuous network of eutectics.

2 . LITERATURE REVIEW.

The microstructural control exercised during spray forming process provides an exciting new opportunity to the development of materials with a superior physical and mechanical properties. Several benefits of this processing methodology are by now well established. Rapid solidification effects inherent in spray deposition process due to high heat exchange rate at the droplet gas interface and also on the deposition surface ensures considerable chemical and micro-structural homogeneity of the spray-deposit . In addition, formation of equiaxed grain morphology and dispersion of ultra-fine second phase particles are often the characteristic micro-structural features of spray formed alloys.

The evolution of micro-structure during spray deposition depends in a complex way on droplet dynamics and their thermal state on the deposition surface. These are controlled by process variables employed to atomize the melt, nozzle-substrate distance and design of spray nozzles.

Process modeling based on solidification and heat flow analysis is often used to suggest that the solid fraction in the spray arriving on the deposition surface is critical to control the micro-structure and porosity of the spray-deposit .Generally, a too high liquid fraction on the deposition surface results in splashing of the melt from the deposition surface by high-velocity gas jets and formation of large size pores due to gas entrapment. In this case, the micro-structure of the spray-deposit resembles with a typical cast structure.Alternatively, an excess solid fraction in the spray generates a large number of porosity due to insufficient liquid phase available to provide bonding of particles during solidification of the spray-deposit.

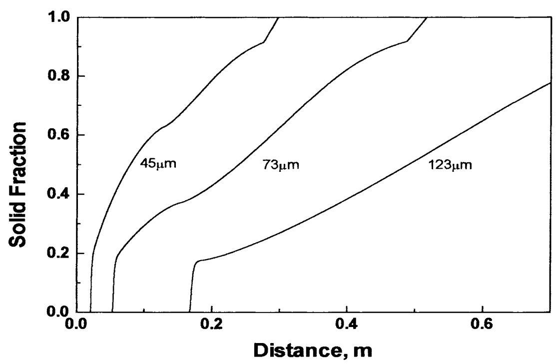
Such a deposit requires secondary processing to reduce porosity and to achieve micro-structural homogeneity of the alloy. In an earlier investigation, a change in dendritic morphology of the primary a-phase to its spherical morphology together with modification in eutectic micro-structure of Al–Si alloy was reported.

In the present investigation variation in morphology of the primary phases induced by spray deposition of a wide range of compositions of Al–Cu alloy is presented. In brief, the process employs an annular convergent-divergent nozzle, with a throat area of 20.5 mm2 and exit to throat area ratio of 3:1, for atomization of the melt. In this process, the gas interacts with the molten metal melt stream at the tip of a flow tube concentric with the gas flow channel. The resultant spray of droplets are deposited on a copper substrate in an environmental chamber.

Table of composition of the alloy and process variables employed during spray forming.

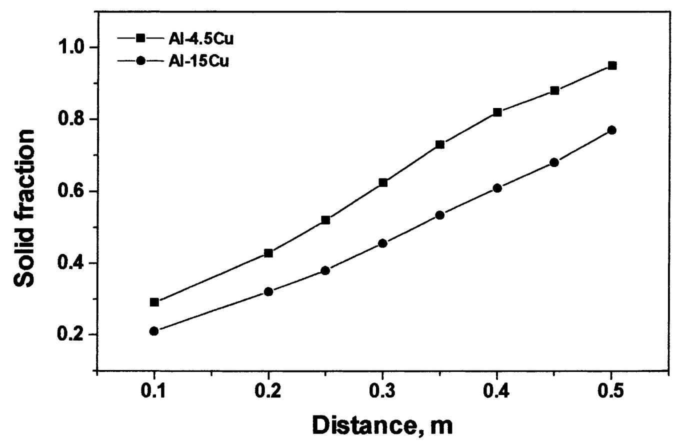
Alloy composition	Melt temperature	Gas pressure	Gas/melt flow ratio	Deposition distance
Al–4.5 Cu (Wt%)	750 (°C)	1.2 (MPa)	1.1	0.30
Al–15 Cu (Wt%)	750 (°C)	1.2 (MPa)	1.05	0.30
Al–33 Cu (Wt%)	700 (°C)	1.0 (MPa)	0.8	0.35
Al–40 Cu (Wt%)	800 (°C)	1.2 (MPa)	0.95	0.35

The microstructural variation is rationalised in light of the alloy composition and conditions of solidification of droplets during flight as well as the spray-deposit during spray forming process. Subsequent to atomisation of the melt, a wide size range of droplets are generated in the spray. The size and size distribution of droplets in the spray are represented by three characteristic droplet diameters. The sieve analysis data of the atomised powder particles of Al–4.5 Cu al1oy in the present investigation yielded the median particle diameter dm of 73 µm whereas d16 and d84 were 45 and 123 µm, respectively. Rapid solidification effects are induced in small size droplets due to high heat transfer rate at the droplet-gas interface and their large under cooling during solidification. This condition is often desirable to achieve reduced segregation and refinement in grain size. Due to the significant heat sink effect of the spray jet as it entrain large volume of gas at ambient temperature, the spray comprises solid particles and fully or partially liquid droplets during time of deposition. The fraction of solid changes with size of droplets and their fight distance from the atomisation zone. Such variation of solid fraction (fs) for three characteristic droplet diameters of Al–4.5 Cu alloy.



Variation in solid fraction as a function of distance in three characteristic droplet diameters representing size distribution of droplets in the spray graph shown above.

In Al–4.5 Cu alloy, due to a large volume fraction of the primary phase and spatial constraint, the growing inter- faces from different nucleation centres converge at common boundaries to provide an equiaxed grain morphology of the primary a-phase. However, as the volume fraction of the primary a-phase is less in Al–15 Cu alloy, its isolated debris particles can not grow to form equiaxed grain and isolated morphology of particles are retained with a particulate eutectic morphology in the inter particle regions.Variation in ag gregated solid fraction of the spray as a function of deposition distance is shown below.



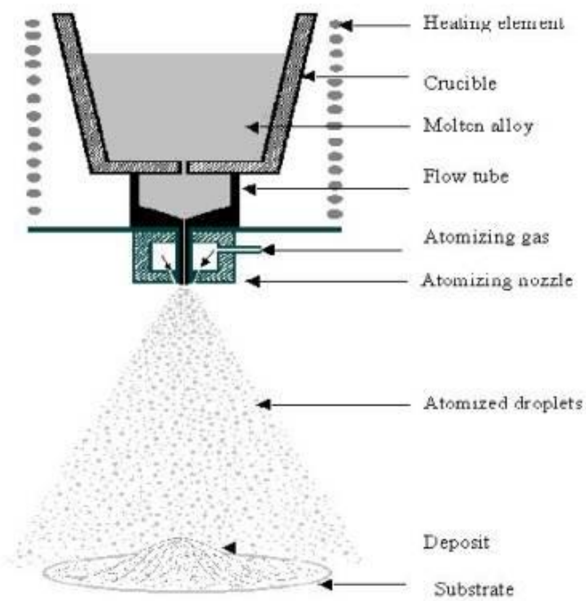
3 . METHODOLOGY.

3.1 SPRAY ATOMIZATION.

The figure shows the schematic diagram of spray atomization process in rapid solidification. The aluminium copper alloy metals is melted into a furnace upto its superheated condition and then it is poured into a crucible. The crucible is placed on a table having small hole gap at the bottom. Where a nozzle is fixed for spraying purpose. The stopper rod is used to stop the flow of molten metal. The inert gas pipeline attached to nozzle setup for pressing spray of molten metal and also preheated coil is connected to nozzle to maintain constant temperature of molten metal throughout the process. The elevating table placed at the bottom of the nozzle to collect the molten metal and table is moves up and down according our requirement.Here we used the Crucible which is made up of clay-graphite. Because it withstand with high temperature up to 2500 c. The material which is used for melting is aluminium-silicon alloy. (melting temp 577 c).To preheat the crucible we are providing it with

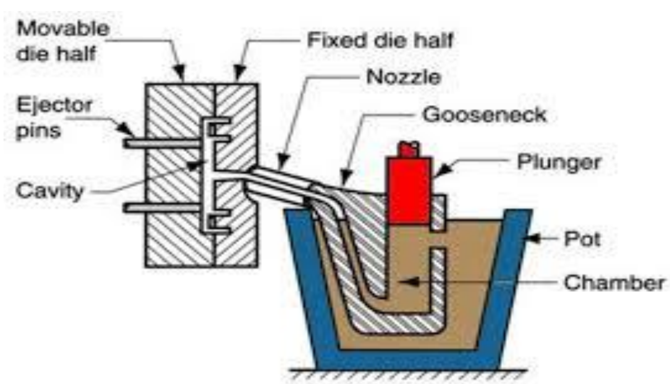
International Journal of Scientific & Engineering Research Volume 11, Issue 6, June-2020
ISSN 2229-5518

heated coils to avoid solidification as when the molten metal is poured into the crucible.



3.2 DIE CASTING

Firstly we melt aluminum copper alloy in the crucible and obtain the melt and then with the help of a tongs we pour the liquid molten metal melt into a mold and leave it for cooling and obtain the shape of the mold. Once the mold reaches room temperature we extract the casted alloy out of the mold and examine it further.



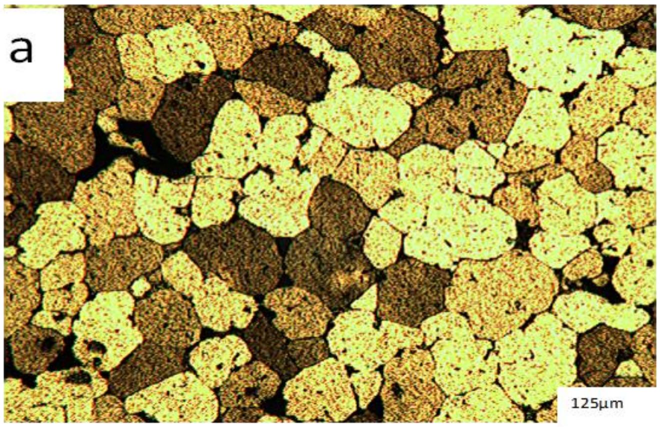
Here we compare the castings obtained from both the methods. Firstly we examine the properties of the alloy when it is produced out of die casting , alloy which is aluminum 4.5wt% cu . Then we examine the castings made of spray casting and rapid solidification of aluminum 4.5wt% cu and obtain our conclusions.

4. RESULTS AND DISCUSSIONS.

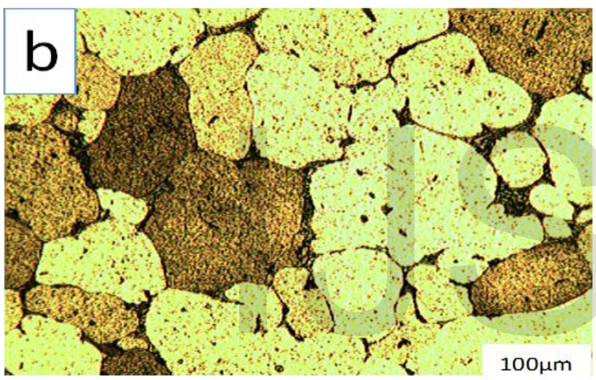
4.1 OPTICAL METALLURGICAL MICROSCOPY.

The cooling rate is 10^3c/sec. Coarse grains are formed because of slow cooling rate. Nucleation slides are less. Secondary phase CuAl2 inter metal located along grain boundaries. In some cases CuAl2 also distributed inside the grain. Grain size is measured using line interpretation method. In between we can see 30 to 40 microns strain structure because of very fast cooling rate. At the centre of the mould cooling rate is slow .Hence the strain side is large and these grain coarse grains at the boundaries equaled. Cooling rate is very poor hence smaller grains are formed. These grains at the boundary are very fine in between the centre and boundary of mould is elongated grains can be formed. After obtaining the casts we polish it and after 4-5 stages of polishing the to remove the scratches and then we etch it which reacts with the metal and the following results were obtained.

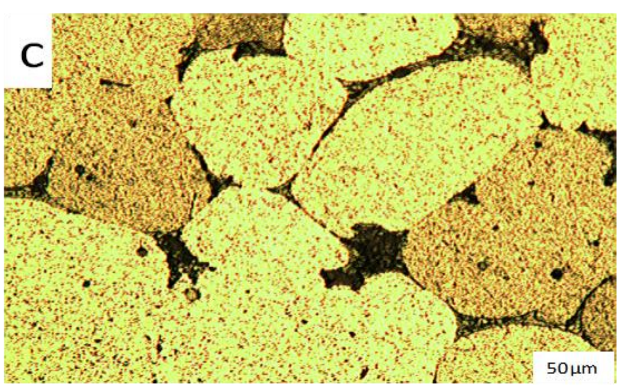
Below we can see the micrographs of surface topography of the die casted aluminum 4.5wt% cu obtained from optical metallurgical microscope



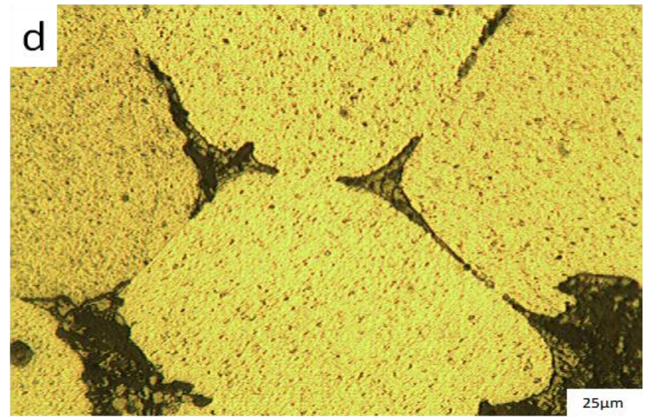
a. surface topography of the alloy at 50x magnification. With density of 2.72g/cc .



b. surface topography of the alloy at 100x magnification with density of 2.74g/cc



c. surface topography of the alloy at 200x magnifiction with density of 2.75g/cc.

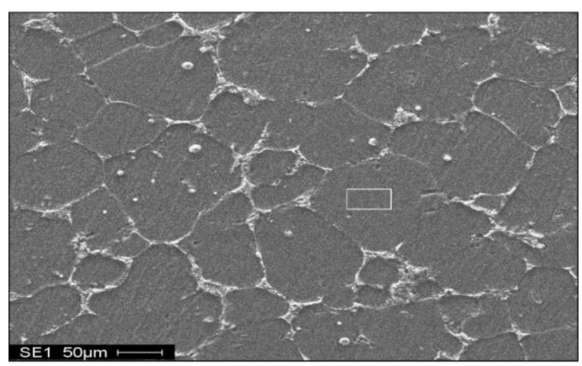


d. surface topography of the alloy at 500x magnification with density of 2.77g/cc.

The density of the alloy is acquired through water displacement method of all the densities which is **2.745**. All the images were captured by the optical metallurgical microsope (OM).

4.2 ELEMENTAL ANALYSIS (EDAX REPORT)

Further we take images of the alloy with the help of scanning electron microscope (SEM).

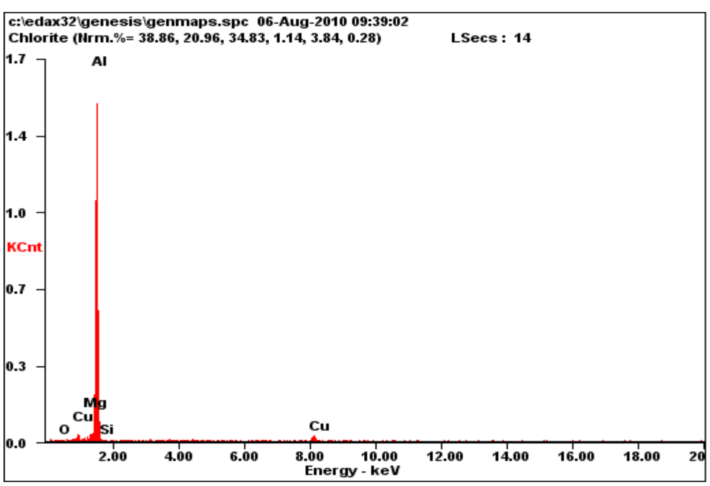


KV 30.0 MAG 200 TILT 0.0 MICRONSPERPIXY 0.625

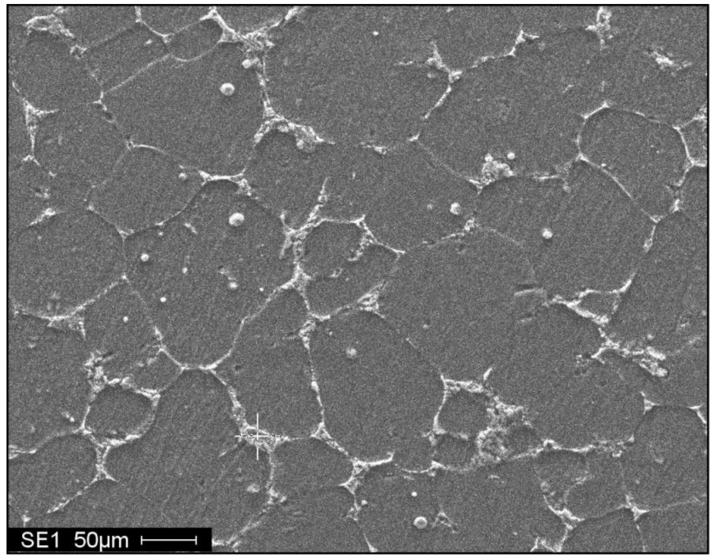
Here we can see two phases in the image captured by the SEM the dark phase and the bright phase. This is box edax result. Above box highlights the presence of other elements and their compositions in the alloy below the values are enlisted in a tabular column.

Element	***Wt%***	***At%***
OK	01.37	02.35
MgK	01.14	01.28
AlK	92.35	93.87
SiK	00.51	00.49
CuK	04.64	02.00
Matrix	Correction	ZAF

The peaks can be observed in the graph as mentioned which is obtained by scanning electron microscopy. The composition table shows the presence of copper alloyed with aluminum.



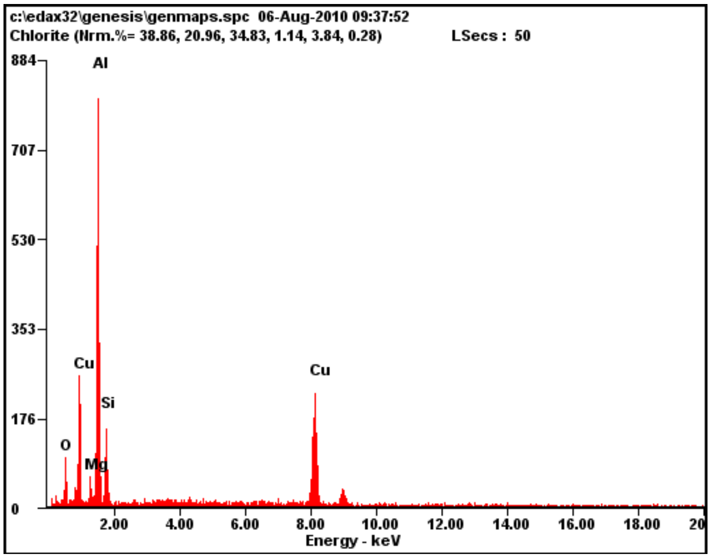
Further we talk about the bright phase which is captured by the SEM, this type of analysis is spot edax and the report is as follows.



KV30.0 MAG 200 TILT 0.0 MICRONSPERPIXY 0.625.

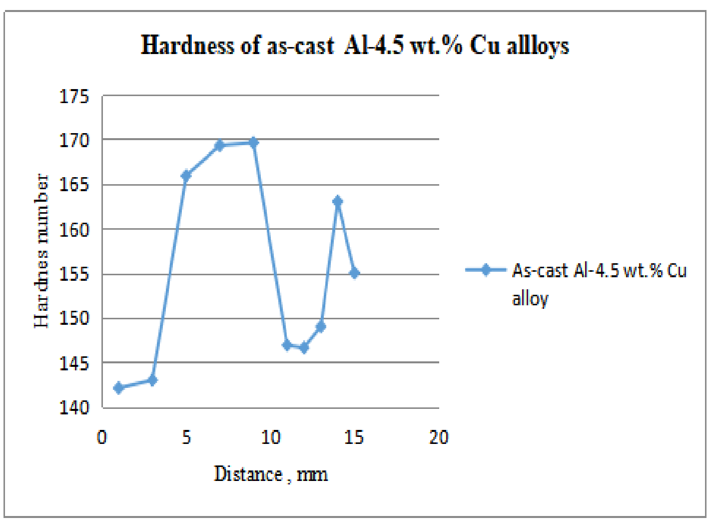
Below the composition table represents the presence of elements at the spot (plus mark) which is marked in the above image.

Element	***Wt%***	***At%***
OK	12.22	22.20
MgK	02.87	03.43
AlK	46.08	49.64
SiK	12.06	12.48
CuK	26.76	12.24
Matrix	Correction	ZAF



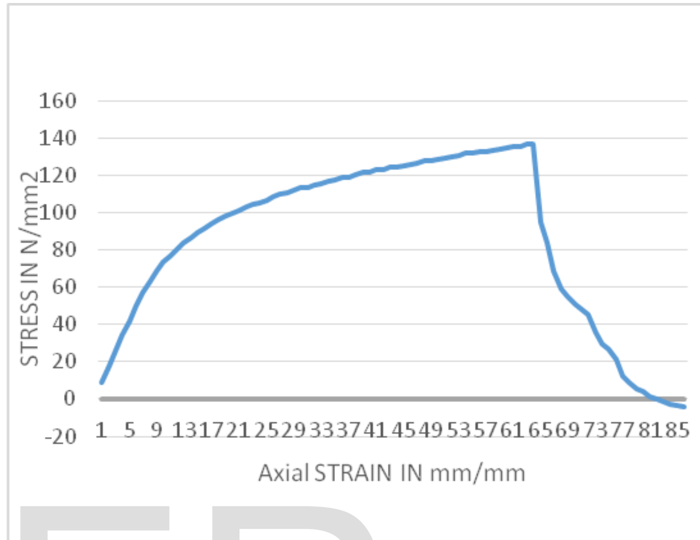
4.3 VICKER'S HARDNESS TEST.

The hardness test on the sample which was made out of die casting bears the following results when tested for hardness using Vicker's hardness test. The hardness of the sample at different locations was found to be varied from 140 HV to 170 HV.



4.4 TENSILE TEST.

Tensile test was conducted on the obtained sample of aluminum copper alloy to get the ultimate yield point and falling values have been plotted in the graph. The 0.2 % yield strength and ultimate tensile strength of the samples are 95 MPa and 139 MPa respectively.



CONCLUSIONS.

The grain size of al cast alloy is **120** microns due to slow cooling rate. Hardness number is **169.6** of the test sample determined by vicker's hardness test. The density of the alloy is acquired through water displacement method of all the densities which is **2.745**. The yield point of the stress is 100 N/mm^2. The total strain of the sample is observed as 0.0032 mm/mm. At the ultimate yield point the stress is found to be 130N/mm^2 and strain is 0.01432 mm/mm. At the breaking point it is observed that the stress is 150 N/mm^2 and the strain is 0.0243 mm/mm.

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